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A REMOTE SENSING EVALUATION OF FOREST RESOURCES IN INDIANA'S COASTAL ZONE MANAGEMENT AREA

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Abstract

Indiana's Department of Natural Resources in cooperation with Purdue University's Laboratory for Applications of Remote Sensing have recently completed the preliminary phase of a remote sensing demonstration project. LANDSAT digital data, computer-assisted analysis techniques and ground surveys all played significant roles in completing a forest inventory for a test site in northern Indiana. The accomplishments of this first phase, along with economic considerations and time factors, will all be discussed.

The remote sensing application portion of this project were performed under Grant NGL15-005-186, NASA Office of University Affairs. Field work was supported by funds from the Indiana Department of Natural Resources.

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INTRODUCTION

Indiana does not quickly come to mind when discussing coastal zone resources. Although, generally landlocked, 26.7 kilometers (43-miles) of northern Indiana abutts the southern most shores of Lake Michigan. This, however, allows the State to receive administrative support for the development of coastal zone management programs. These funds are made available under Public Law 92-583 which congress passed in 1972 as the Coastal Zone Management Act (1).

In the discussion which follows we will describe how one branch of State government used machine-aided analysis of LANDSAT digital data to inventory coastal zone resources. Since the project is just completing the first of its two phases preliminary results and conclusions will be presented. The significance of utilizing LANDSAT data in terms of costs and anticipated inventory efficiency will be discussed.

PHASE I

Early in 1976 members of the Division of Forestry within Indiana's Department of Natural Resources (IDNR) met with members of Purdue University's, Laboratory for Applications of Remote Sensing (LARS) to discuss potential applications of remote sensing in forestry. During that meeting, the State's Coastal Zone Management Planning Program was discussed. Since the area of interest had been analyzed as part of another project, and the results were available, LARS suggested that they might be useful to IDNR.

Specifically, IDNR had been given responsibility to collect and quantify information relating to the natural resources within the coastal zone study site. The Division of Forestry was most interested in current information about the timber resources. Initially, general information relating to the areal extent of forest cover in portions of Lake, Porter, and La Porte counties was needed by early May 1976. Since the information required was of a general nature we felt this could be easily supplied from LANDSAT analyses.

Jointly, both organizations developed the objective:

> To provide current information about the forest resources of the Indiana Coastal Zone through application of computer-assisted analysis of LANDSAT data and ground inventory.

LARS would take the responsibility of providing computer-classification maps and information about the areal extent of the forest resource. IDNR would conduct ground surveys to quantify the ecological parameters of the forest.

The study area, figure 1, includes approximately 150,000 hectares (375,000 acres) of land, located within the physical drainage of Lake Michigan in all or parts of 19 U.S.G.S. 7½ minute quadrangle sheets. In addition to its biotic and geologic diversity the study site is unique in that it lies within easy commuting distance of 10 million people, it supports a National Park and Lakeshore, in addition to heavy industry in Gary and Hammond.

Out first concern was the forest inventory. Since 1972 LARS has been involved in forest mapping in the west (2) and the south (3) with a moderately high level of success. Over the past year we have been heavily involved in a project mapping the central hardwoods, primarily the Oak-hickory type, in south-central Indiana (4). The Coastal Zone project offered a unique opportunity to become involved with an actual user defined inventory operation. Furthermore, the site, although predominantely central hardwood in composition is part of the transition zone with the northern hardwood in composition is part of the transition zone with the northern hardwood zone (5). This would offer a unique mixture of forest classes.

MATERIALS AND METHODS

LANDSAT-1 data, collected over northern Indiana on June 10, 1973 (Scene I.D.: 1322-16045) was the primary data source. Analysis of this data was supported by small-scale high-flight color infrared photography collected as part of the Corn Blight Watch Experiment, in July of 1971. One field trip was made in early spring (1976) to support the computer analysis.

The analysis sequence followed the flow identified in figure 2 (6). In summary, once the data has been received, reformatted and geometrically corrected the analysis begins. During this preprocessing time the analyst collects any ancillary data that is available. In this case ancillary data consisted of U.S.G.S. 7½ minute quadrangle maps and the small-scale infrared photography. Prior to analysis candidate training areas are selected.

Candidate training areas are selected to represent the range of ground cover diversity in the study site. Seven areas, scattered north to south along the western edge of the site were selected

for training. Together these composed less than one percent of the total study area.

The seven training areas are located in the data and clustered. The cluster groups or spectral classes are identified for informational content with the aid of the small-scale photography and a zoom transfer scope. Statistics from each test site were pooled, the test sites were classified and these results were field checked. Modifications in the class structure were made prior to the final classification. There were a total of 33-spectral classes that composed the level I classification for: Urban, Agriculture, Forest Wetlands and Water.

The final products of the classification included:

- o Calcomp maps at 1:250,000 scale for the forest class only. Minimum mapping unit size equals 10 acres (Figure 3).
- o Individual alphanumeric printouts at a scale of 1:24,000 for each quadrangle for each of the four spectral classes for forest. Mapping unit equals 1.1 acres (Figure 4).
- o General summary tables, acreage, by class, mapping level, study site and quadrangle (Table 1 and 2).

The small scale calcomp map was embellished through the addition of geographic features (figure 3), and it and the tables comprised the Phase I report. The 1:24,000 scale printouts were used as a basis for drawing the ground samples.

Alphanumeric printouts (figure 4) were also made for each of the 19 U.S.G.S. quad sheets. Forest was the only class displayed, and it was separated into its four component spectral classes. Each symbol element represents approximately 1.1-acres on the ground. Acetate copies of the U.S.G.S. quads were made to overlay on the computer printout. This was to allow for each in locating the ground plots by the field crews.

The most important information provided from the computer analysis was the estimation of the acreage of forest land in the study site. In the three months which were available, machine-assisted analysis of LANDSAT appeared to be the only reasonable method to estimate this information. Without the acreage estimates for forest land;

1. The States preliminary coastal zone management plan would have been incomplete, and

2. The development of a ground sampling strategy and allocation of sample plots would not have been possible.

Field data were collected during the summer of 1976. Two individuals working nine weeks were able to collect data, which included grouped samples for 291 forest tracts and approximately 1500 prism points. We estimate that the ground survey was a little better than one percent of the entire study site of a five percent inventory of the forest land. Results from the ground plots provided one measure of classification accuracy, but only with regard to the forest classes. According to the field data, our overall forest classification accuracy was 82 percent. This accuracy is expected to increase for Phase II when supplemental training fields are selected, and the site is reclassified. Also during Phase II the spectral class definitions will be refined to reflect ground conditions. Based on a new classification additional survey points will be allocated to supplement:

1. The needs of the Coastal Zone Inventory, and

2. Update commercial timber inventory information in the study area.

ECONOMIC CONSIDERATIONS

An important point to remember is that computer-assisted analysis of LANDSAT data was not selected for this inventory because of any anticipated cost saving over other means of acquiring the information. The primary consideration was time. LARS had the data and resources available to complete the analysis by the deadline. IDNR had a need and an interest in future applications of the technology. For these reasons the project developed.

As we progressed and solidified our goals and objectives, economic considerations began to surface. Computer-analysis of large areas covered by LANDSAT has some obvious cost advantages over conventional photo-interpretation methods. Of course this assumes that the user has confidence in the map and classification accuracy, and does not expect more from the analysis than the data can supply. Obviously for forest inventories some form of multi-level sampling, utilizing LANDSAT, air-photos and ground surveys could be expected to yield satisfactory results cost-effectively. We hope to address this approach during the next phase of this project.

For the sake of comparison we have assumed inventory costs using available U.S.D.A. photography. Tables 3 and 4 list the estimated costs involved with LANDSAT and PI analysis. Table 5 presents a comparison of the two methods.

The cost effective ratio just slightly favors the LANDSAT analysis. For this example there is little or no difference in real costs between the methods. However, these are preliminary results and not all costs have been accounted. In fact, the photo costs are no more than estimates based on our past experience, and the knowledge of the complexity of interpreting the central hardwoods. Since we are in the process of finishing the Phase I inventory, we will refrain from any detailed discussion of ground data collection. The 1976 field results indicate that the average cost associated with each of approximately 1500 prism points was $5.90 per point.

The real benefit of the LANDSAT data, which is not reflected in the costs, was its availability. Since the data was in-house, there was no delay in beginning the analysis. Under the assumed situation with the air photo analysis there would have been a delay, anywhere from 8 to 15 weeks, in acquiring the data. If one considers this time in addition to the interpretation and map and tabular presentations, we would have been hard pressed to meet the deadline.

CONCLUSIONS AND DISCUSSION

Given what has preceded we are left to look to the future and reflect on past accomplishments. Since we met the general objective of providing information about the areal extent of forest in the coastal zone study region in the allotted time, we were successful. But there are other accomplishments worthy of note. Among there are:

- Relatively little effort was expended in acquiring the results.
- IDNR exhibits an increasing degree of confidence in the classification procedures.
- Without the LANDSAT classifications the extensive collection of field data would have been impossible within the allotted time frame.

- Given positive results from this demonstration future application of this technology within state programs is receiving consideration.

- Even though current cost figures give LANDSAT data a marginal edge, we anticipate that this gap would widen in LANDSAT's favor when broader and more intensive inventories are contemplated.

- Given good correlation between the spectral classes and timber stand characteristics, LANDSAT data can be expected to play a significant role in future multi-level inventories of the central hardwood region.

As this project matures, we expect to make more positive statements regarding the application of machine-assisted analysis of LANDSAT data. The utility of applying this data in a multi-level sampling scheme will be evaluated. As well as the cost of supplying this information to the user community.

Lest we be mistaken for the last of the knights in shining armor, we need to reflect on the problems encountered. Like almost any project this one would have benefitted from better planning. Although the general objective never varied, sub-objectives seemed to sprout like weeds in a field. All objectives should have been identified and prioritized at the beginning of the project. If we had undertaken to accomplish this, there are areas in the project flow where things would have been done differently.

For instance, in mid-winter when the analysis began we never concerned ourselves with how the field sample sites were going to be allocated in the summer. Obviously, this should have been one of our prime considerations. Likewise, manipulating the alphanumeric printouts in the field was a cumbersome proposition. A little forethought and some pre-planning could have alleviated this problem.

These are just a few examples of the little problems that hamper forward progress. We were lucky in that we identified our shortcomings early. At the time we analyzed how or what should have happened. In this way we are slowly structuring a plan for future inventories.

In this respect the coastal zone mapping project is an important demonstration of remote sensing systems capabilities within the State of Indiana. If user confidence and

understanding can be maintained, we can expect to continue advancing the technology. Positive cost ratios will help sell this approach in light of increased pressures for resources and in increased cost of information gathering in the face of diminishing operating budgets.

References

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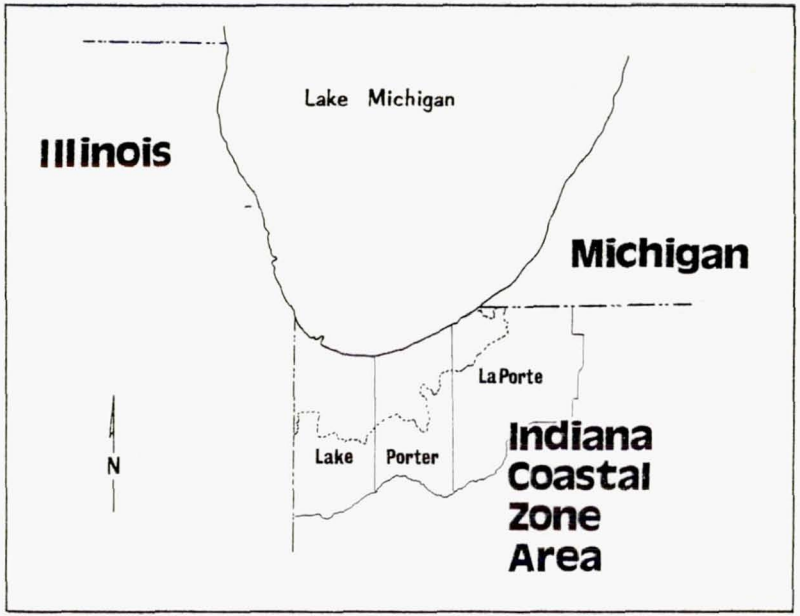

Figure 1. Test site location.

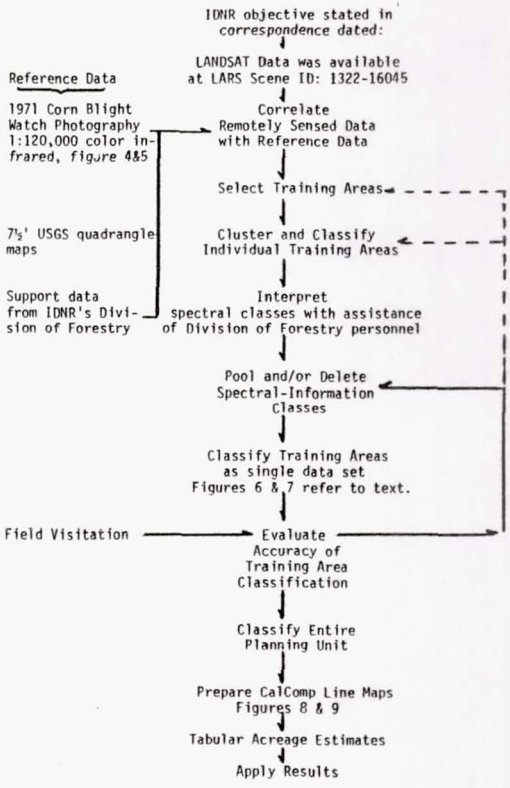

Figure 2. Project flow.

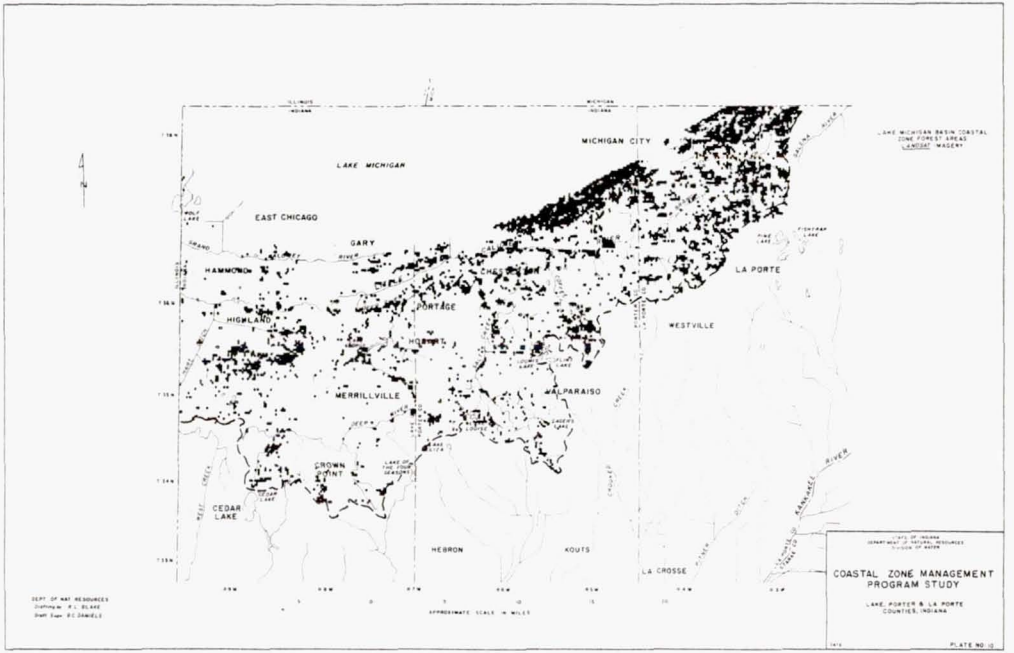

Figure 3. Calcomp map of forest classes.

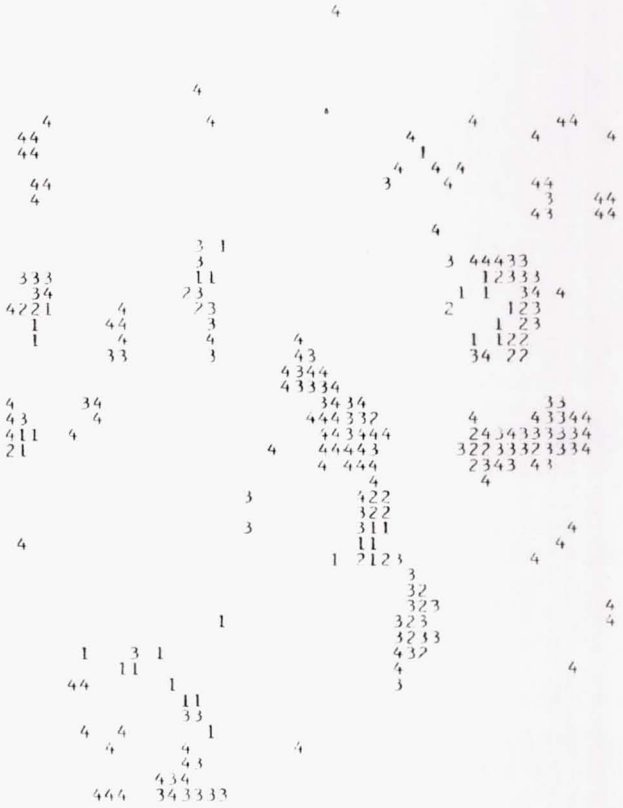

Figure 4. Alphanumeric printout of four spectral classes of forest.

Table 1. General summary table for level I classes.

Class	Acres	Percent
Urban	51161	13.2
Ag	173687	44.6
Forest	72516	18.6
Wetlands	56606	14.6
Water	35124	9.0

*Classes identified through computer-aided analysis of LANDSAT Data source LANDSAT Scene Id 1322-16045 collected 10 June 1973.

Classes	Acreage	Percent Area
Urban (commercial, industrial, new residential)	7034	1.9
Residential (urban mixed with vegetation)	40575	10.4
Mixed Urban (urban, bare soil)	3370	.9
Rural (Ag and urban class mix)	88192	22.7
Ag (cropland, pasture	85495	22.0
Upland Forest 1	10362	2.6
Upland Forest 2	13208	3.5
Forest	22887	5.8
Dry Forest	26059	6.7
Shallow Marsh	11202	2.9
Shrub	29689	7.6
Shrub - Marsh 1	5067	1.3
Shrub - Marsh 2	10648	2.7
Shallow Water	6250	1.6
Lake Water (primarily Lake Michigan)	28874	7.4

Table 2. General summary table for level II classes.

Table 3. Costs associated with computer assisted LANDSAT analysis of the Coastal Zone Management Area.

I.	Data Acquisition	
	purchase of CCT's	$ 200
II.	Preparation	
	reformatting and geometric correction	525
III.	Training Set Selection	
	130 man-hours*	937
	ground reference photos and maps	30
	field trip 4 man-days	276
IV.	Computer Time, Mapping	
	classification and training	1013
V.	Map Preparation	
	1:250,000 document map, CALCOMP	100
	field maps, alphanumeric printouts	257
	Total cost	$3338

*Estimated annual salary, trained analyst, $15,000 not including overhead.

Figure 4. Estimated costs associated with photo inventory of the Coastal Zone Management Area.

I.	Data Acquisition	
	119 black and white photos and photo index sheets	$ 250
II.	Preparation	
	indexing and filing, 40 man-hours*	288
III.	Training Site Selection	
	preliminary site evaluation, 24 man-hours	173
	base maps and supplies	80
	field trip, 10 man-days	880
IV.	Mapping Time	
	forest maps/U.S.G.S. quad 10 man-hours/quad equivalent 15 full quads	1082
V.	Map Preparation	
	1:250,000 document map, 30 man-hours	216
	field maps, 7 man-hours/quad	757
	measuring and recording acreages, 3 man-hours/quad	324
	Total cost	$4050

*Estimated annual salary, qualified photo-interpreter, $15,000, not including overhead.

Table 5. Comparison of LANDSAT and photo inventory cost estimates.

		LANDSAT	Photo
I.	Data Acquisition	200	250
II.	Preparation	525	288
III.	Training	1243	1133
IV.	Mapping Time	1013	1082
V.	Map Preparation	357	1297
	Total	3338	4050
	Cost/Hectare	.0223	.0270
	Cost/Acre	.0086	.0104
	Cost Effective Ratio	1:1.2	